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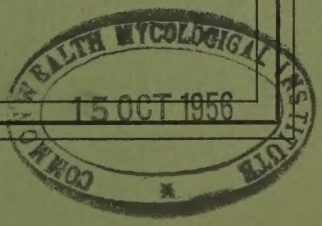

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N.A.A.S.
QUARTERLY REVIEW

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NO. 33 AUTUMN 1956

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REVIEWS AND ABSTRACTS

In this section of the N.A.A.S. Quarterly Review, it is intended to survey current research and experiment in agriculture, horticulture and the allied sciences applicable to the work of the National Agricultural Advisory Service. It will not be possible, of course, to cover more than a small part of this wide field in each issue.

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Applications of Isotopes to Soil and Fertilizer Research

G. E. G. MATTINGLY
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ISOTOPES are atoms having chemical properties identical with those of the related element, but differing from them slightly in mass. They may be either radioactive, emitting α, β or γ rays, by which they are detected, or stable, when they are detected and estimated by physical methods which make use of their different mass. One of the isotopes of phosphorus, which has been widely used in fertilizer research, has a mass of 32(H=1) and is denoted ^{32}P to distinguish it from the most abundant natural isotope of phosphorus, ^{31}P. Most applications of isotopes in research involve the synthesis of chemicals containing minute amounts of a radioactive isotope; this process is usually referred to as "labelling" or "tagging" and the isotope is commonly described as a "tracer".

Before 1934, radiotracer techniques could be used only with a few naturally-occurring radioactive isotopes, such as thorium. Between 1934 and 1939, however, a number of isotopes, not occurring naturally, were prepared in a cyclotron and, in 1940, Arnon, Stout and Sipos [1] used ^{32}P prepared in this way to show that phosphorus was translocated from nutrient solutions into ripening tomato fruits. By 1947, at least nineteen different isotopes had been used in studies on plant nutrition [2]. Radioactive isotopes prepared by neutron irradiation in atomic piles in the United States, Canada and Great Britain have been used widely in medicine, industry and agricultural research since 1946. Several important stable isotopes, separated by physical methods, have also been used extensively as tracers in research.

This review deals only with the techniques used and some results obtained with isotopes in soil and fertilizer research; advances in plant physiology and nutrition resulting from the use of isotopes are not discussed in any detail. Most examples have been chosen from field and pot experiments, and illustrate only a few of the many applications of isotopes to soil science during the past decade. In order to discuss this relatively new and specialized technique, and to indicate its scope and limitations, some account of experimental methods is given before discussing results.

Isotope Properties and Measurements

Radioactive isotopes "decay" or break down at a rate proportional to the amount of the isotope present; this rate is a fundamental property and is not changed by heat or pressure or chemical reaction. Rate of decay is measured most conveniently by the "half life", or time required for the activity to fall to one half its initial value, and may vary from fractions of a second to millions of years. This rate determines

whether an isotope is suitable for a particular line of research, for it is seldom possible to estimate isotopes accurately for periods longer than ten half-lives. As an example, the ^{42}K isotope of potassium has a half-life of only twelve hours and cannot therefore be used for more than five days, an obvious limitation of its use in fertilizer experiments.The quantity of a radioactive isotope commonly used in research is minute, and is measured by the amount of radiation emitted. The unit of measurement is the microcurie (μC), which can be loosely defined as that quantity of an isotope emitting the same total ionizing radiation as one microgram of radium.

Radioactive isotopes are also detected and measured by the radiations they emit. Useful and permanent visual records can be obtained by placing radioactive materials, for example, plants grown in isotope-labelled solutions, on the surface of a photographic plate. These "radioautographs" show clearly the distribution of the isotope in plant tissues. Quantitative measurements of radiations are made with a counter tube consisting, in its simplest form, of a gas-filled chamber with a central wire maintained at a positive potential. The gas, when ionized by radiation, produces a small pulse of current which is amplified and counted by electronic equipment. To obtain reproducible results, each sample must be placed so that the same fraction of its radiation falls on the counter. This is achieved either by counting samples as a gas, a liquid or a chemical precipitate prepared under reproducible conditions. Usually ^{14}C is counted as a gas or as a precipitate of barium carbonate, preferably using a windowless counter (Plate I) to avoid absorption of the low-energy β-rays by the window; ^{45}Ca and ^{35}S are counted as precipitates of calcium oxalate and barium sulphate. Some isotopes, emitting high-energy β-rays, for example, ^{32}P, can be counted in solution using special counting tubes. Plant samples containing tracer quantities of isotopes are ashed, by wet or dry methods, and the isotope estimated either in solution or after precipitation. "Briquettes", prepared from compressed plant material, can be used for counting some isotopes [3].

Stable isotopes, such as ^{13}C or ^{15}N, have not been widely used yet in soil research because of their cost, the difficulty of detecting them after dilution in soil or in plants, and the skill and apparatus required to estimate them quantitatively.

Radiation and Handling Precautions

All radioactive materials must be handled carefully to avoid contamination of equipment and to minimize exposure of the operator to ionizing radiations. Radiation hazards depend primarily on the chemical properties, the quantity and the half-life of isotopes. Brick, concrete or lead walls provide effective screening from isotopes emitting γ-rays, and $\frac{1}{2}$-in. perspex or glass from those emitting β-rays. When handling isotopes, there is a much greater risk from absorption through the

lungs and stomach than from direct radiation. Isotopes with long half-lives (^{45}Ca, ^{89}Sr) that are not rapidly excreted are all dangerous to handle because, if taken into the body, they concentrate in bone and damage the bone marrow. Isotopes that are eliminated rapidly from the body or have short half-lives (^{24}Na, ^{42}K) are less dangerous.

Rubber gloves give protection during chemical manipulations, and preparative work is done in efficient fume-cupboards or in enclosed glass-topped boxes. Highly-active material can only be handled with tongs or by remote control, though these precautions would not be necessary for most investigations using the tracers that are described below.

Sources of Error in Isotope Studies

Radiation from isotopes may damage plant or animal tissues sufficiently to alter their growth or metabolism, and control treatments without a tracer must therefore be used, either to ensure that the amount of damage is negligible, or to estimate its extent. Damage has been observed at very low levels of activity, histological changes occurring in barley grown in solutions containing only $2\mu C$ ^{32}P per litre [4]. Using ^{32}P, Martin and Russell [5] found that the most consistent symptoms of radiation damage in plants grown in water culture were an increase in the proportion of phosphate which was translocated to shoots and a reduction in root weight. Radiation damage to soil-grown crops in pot and field experiments is generally less than in water culture [6, 7, 8 and 9]. Addition of ^{32}P in larger amounts than those normally used in pot experiments can depress microbial activity and reduce the CO_2 production and the ammonia and nitrate content of soil [10].

It has been suggested that isotopic exchange (see below) between a labelled fertilizer and soil may result in erroneous estimates of fertilizer uptake. This problem has recently been discussed at length [11]. In most of the work reviewed here, however, the authors have assumed that the amount of isotope detected in a crop measures fertilizer uptake.

Preparation of Radioactive Fertilizers

Fertilizers cannot be labelled uniformly with a tracer merely by adding the isotope to commercial fertilizers. For example, ^{32}P-labelled superphosphate, must be prepared by adding a small quantity of phosphoric acid, labelled with ^{32}P, to the sulphuric acid used to dissolve mineral phosphate. Dicalcium phosphate, calcium metaphosphate and α-tricalcium phosphate have been prepared in the United States [12] by methods that ensure uniform labelling of the phosphate, and have been used in field trials. Rock phosphates cannot be labelled in this way; although there have been reports of experiments in which rock phosphates made radioactive in an atomic pile have been used [13], this method of labelling is not wholly satisfactory because the chemical form of some of the phosphate can be changed by neutron irradiation.

Distribution of Radioactive Fertilizers in Field Experiments

Radioactive fertilizers have usually been distributed by drilling so that the active material is immediately covered by soil. Commercial drills are not suitable since they become heavily contaminated and seldom apply small dressings reproducibly on small plots. Special machines for this purpose have been designed and used in the United States [14] and satisfactory results have been obtained in this country [15] with a small one-row unit designed originally for fertilizer placement for horticultural crops. This machine (Plate I) was modified slightly for radioactive work by covering the fertilizer hopper with a Perspex shield and protecting all metal parts with paint. Labelled fertilizers can also be broadcast on to soil or placed in seed drills by hand without appreciable hazard in calm weather.

Results with Radioactive Fertilizers in Field Experiments

Extensive series of field experiments using radioactive fertilizers have been carried out only in the United States and Canada; a review of Canadian experiments will appear soon [16] and so they are not described here. Since 1952, a few similar field trials with radioactive superphosphate have been carried out in this country. Five or six different phosphate fertilizers were tested in the United States on a variety of crops; the fertilizers were applied broadcast, or drilled or rototilled into soil, and the experiments were repeated on contrasting soils, sometimes for more than one season. The labelled fertilizers, which are expensive, were usually applied only to one or two rows on each plot, an equivalent amount of unlabelled fertilizer being used on the remainder of the plot. In addition to yield and total phosphorus uptake, the uptake of fertilizer can be measured in such experiments from the radioactivity in the crop.

Phosphorus absorption from a fertilizer generally increases with the amount applied [17, 18 and 19], but differences in fertilizer uptake as a result of both the method and rate of application often become smaller during growth [19 and 20]. In most field crops the percentage of phosphorus that is derived from a fertilizer usually decreases as the root system develops [19, 20 and 21]. Because of the high phosphorus content of their seeds or tubers, potatoes and large-seeded crops take up only a small percentage of their phosphorus from a fertilizer early in their development [17]; in shallow-rooted crops (e.g., oats and barley) the proportion of phosphate coming from the fertilizer is higher [21 and 22], and remains more nearly constant during growth.

The total quantity of fertilizer phosphorus taken up by crops depends so much on the method of application, the phosphate status of the soil and on the climate, that it is not possible to draw any general conclusion from the large amount of recent work on this problem. A few typical percentage recoveries of phosphorus, however, are given in the following table:

Table 1

Percentage Recoveries of P_2O_5 from Superphosphate by Several Crops, Determined from ^{32}P Measurements

Crop	Amount of P_2O_5 Applied	Percentage Recovery	Method of Fertilizer Application	Remarks	Reference
	lb/acre				
Potatoes	100	4.2	Bands, 3 in. to side 2 in. below seed	High soil P	17
„	100	14.5		Low soil P	
Oats	40	10 to 22	Broadcast	Range on three soils	22
Barley	11	8 to 25	Drilled with seed	Range on two soils in two years	15
Maize	20	14.3	Single band at seed level	—	20
	40	9.1			
	80	7.8			

Tracer experiments have shown very clearly that small dressings of phosphate often greatly increase the uptake of soil phosphorus by crops [18 and 23], probably because they increase the extent of the root system. In experiments comparing forms of phosphate, calcium metaphosphate applied in bands was equivalent to superphosphate for cotton and corn, and supplied more phosphate to the crop than α-tricalcium phosphate [24]. With oats, wheat and barley [21 and 22], more phosphate was taken up from superphosphate applied broadcast or in wide bands, than from the other two phosphates. In the American experiments, dicalcium phosphate was invariably inferior to superphosphate [19, 21, 22 and 24]; moreover, the uptake from dicalcium phosphate, unlike superphosphate, was not greater when drilled than when broadcast [19].

At four sampling dates, more phosphate was taken up by sugar beet from dicalcium phosphate applied in wide bands with the seed, than from a narrow band 4 in. from the seed, but uptake from superphosphate and calcium metaphosphate was greater from the narrow band of fertilizer, except at the first sampling [21]. There was a greater phosphorus uptake by corn when superphosphate and ammonium sulphate were drilled together in a band 2 in. from the seed, than when they were applied in separate bands.

Experiments using radioactive phosphate fertilizers give useful information about the residual value of phosphate in long-term experiments [25, 26, 27 and 28]. The percentage of phosphorus in a crop derived from the labelled fertilizer varies approximately inversely with the phosphate status of the soil. Webb and Pesek [27] obtained excellent

agreement between the increase in crop yield from phosphate residues and the decrease in the percentage of phosphorus in oats that came from a small broadcast dressing of "tagged" triple superphosphate. They found no difference by either method in the residual value of superphosphate and calcium metaphosphate on a soil at pH 6. On a soil at pH 8, residues from superphosphate and calcium metaphosphate were also equivalent and more available to the crop on this calcareous soil than residues from the same quantity of α-tricalcium phosphate or rock phosphate. Mattingly and Widdowson [28], in a similar experiment on an acid soil at Rothamsted, found that the tracer method gave higher estimates of the residual value of superphosphate than did the yield of barley; this they attributed to the uptake of phosphorus, late in crop growth, from fertilizer residues that had been buried by the ploughing.

Fertilizers labelled with isotopes other than phosphorus have only occasionally been used in field experiments. Blume and Hall [29], using monocalcium phosphate labelled with ^{45}Ca and ^{32}P, found that tobacco derived 26-35 per cent of its phosphorus from this fertilizer but only 2-6 per cent of its calcium. Many isotopes have, however, been used in pot experiments, some of which are reviewed briefly below.

Isotopes in Pot Experiments

The limited volume of soil in pots restricts root development so much that the percentage of phosphorus in plants derived from a labelled fertilizer, intimately mixed with soil, remains almost constant during growth. This is in marked contrast to the results under field conditions which have been described above. In pots [30 and 31], it has been discovered that the ratio of soil to fertilizer phosphorus taken up by crops varies inversely with the amount of fertilizer added, so that "A" in the expression below is almost independent of the quantity of fertilizer tested (b):

$$A = b\left(\frac{\text{uptake of soil phosphorus}}{\text{uptake of fertilizer phosphorus}}\right)$$

"A" is measured in mg P per 100g soil, or similar units, and can best be regarded as the "pool" of phosphate that is in equilibrium with the soil solution. Crop yields and phosphorus uptake by crops correlate well with "A" values [32] and with the "surface exchangeable phosphate" measured by isotopic exchange in the laboratory [33 and 34]. "A" values have been determined by similar methods for cations, the "A" value of calcium in soil being about equal to the exchangeable calcium extracted by neutral ammonium acetate [31]. The "A" values of zinc were shown by Shaw, Menzel and Dean [35] to be independent of the amount of $ZnSO_4$ applied, and to vary from 8 to 17 p.p.m. in three soils.

Isotopes, particularly those of nitrogen and phosphorus, have been used to distinguish between nutrient uptake through the leaves and roots of plants. Quantitative measurements of nutrient absorption can be made at different stages of growth by applying tagged solutions of phosphate to leaves and by supplying unlabelled phosphate in the nutrient solution to the roots [36]. Bould, Thomas and Tolhurst [37], using radioactive sodium dihydrogen phosphate, showed that in the presence of adequate nitrogen, a grass cover-crop, cut frequently and allowed to decompose *in situ*, increased the uptake of fertilizer phosphorus by Malling I rootstocks, but did not affect total phosphorus uptake. Some indications that the decomposition of soil organic matter may be accelerated by the addition of fresh plant material to soil have been obtained in experiments using ^{14}C [38].

Use of Isotopes in Laboratory Investigations

Exchange reactions using tracers furnish useful information about the structure and the surface properties of soils, fertilizers and clays [33, 34, 39 and 40]. If, for example, orthophosphate containing ^{32}P is added to a solution already in chemical equilibrium with soil, the ^{32}P is distributed at isotopic equilibrium so that

$$\frac{[^{32}P]\ \text{soil}}{[^{31}P]\ \text{soil}} = \frac{[^{32}P]\ \text{solution}}{[^{31}P]\ \text{solution}}$$

The total phosphate content of the soil and solution is determined by chemical analysis, and the ^{32}P content of the solution by counting; from this equation the total amount of phosphate in the soil that undergoes exchange can then be calculated. "Surface phosphate" determined in this way is closely related to the "A" value measured in pots [33] and has been used, particularly in the United States, as a measure of phosphate "availability". It has been shown by many workers that the "surface phosphate" in soil increases as a result of phosphate manuring [33 and 34]. As an example, the "surface phosphate" of Rothamsted soils unmanured for at least a century is about 3mg P per 100g soil, but, on soils that received heavy dressings of superphosphate up to 1901, and none since, the corresponding values are about 9mg P per 100g [34]. The total phosphorus contents of the soils are about 45 and 65mg P per 100g respectively.

Other quite different applications of isotopes in laboratory investigations include the work of Bridger and Markey [41] who used ^{32}P-labelled phosphoric acid to measure the relative proportions of phosphorus derived from rock phosphate and from the acid in the water soluble, citrate-soluble and citrate-insoluble fractions of triple superphosphate. Heslep and Black [42] used labelled compounds to show that superphosphate, applied at 369mg P_2O_5 per cm^2, did not diffuse more than 3-4cm in four weeks in moist soil at pH 5.5 and very much less in calcareous soils. Recent use of ^{15}N shows that ammonia is utilized in preference to nitrate during the decomposition of oat straw [43].

The Economics of Mechanization

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THE EVER-WIDENING RANGE of machinery available to the agricultural industry inevitably creates a greater variety of mechanization problems for the farmer. The factors which have to be taken into account in finding an answer to these problems are not, of course, solely economic. Husbandry considerations also play a part; for example, the effect on timeliness of operations may often be the deciding factor in the purchase of a particular machine. The reduction of drudgery and the easing of working conditions are also important, not only for their own sakes, but as an essential means of obtaining or keeping labour on farms in the face of competition from other industries. None the less, the economic factor is, to say the least, still as important as any other.

Like any other aspects of farm management, the economy of mechanization can be looked at from two points of view. There is first the narrow costings approach—how much will it cost to do a particular job with a particular machine compared with what it is costing without it? Then there is the wider approach of the possible contribution of a particular mechanization project to the economy of the whole farm.

Machinery Costs and Returns

It is, perhaps, natural that the farmer contemplating the purchase of a particular piece of machinery should first inquire whether the cost of running the machine will be more than outweighed by the value of labour saved. And although it is seldom sound to base a decision solely on the answer to that question, the advisory officer should at any rate be in a position to give an approximate answer. Unfortunately, there are serious gaps in the available information about the running costs of many types of machinery, particularly those of more recently introduced machines. A fair amount of data have been published on tractor and combine costs, and there are isolated reports on a number of other individual types of machinery. Even where average cost figures are available, however, great care must be exercised in using them, for in this matter the application of averages to individual cases can be extremely misleading. There are two reasons for this. In the first place, the range of variation of machinery costs from farm to farm is very wide. So much depends both on the amount of attention paid by the farmer himself to the care and maintenance of his machinery and on the competence of the men who use the machines, both of which can make a tremendous difference to fuel consumption, repair

bills and work performance per hour. The second and equally important factor in cost variation from farm to farm is the influence of annual work output per machine. It is hardly necessary to emphasize the great difference between agriculture and urban industry in this respect, arising from the seasonal nature of farm operations and the relatively small size of farming units.

Machinery Analysis on Four Farms

A series of case studies undertaken by the National Institute of Agricultural Engineering in 1944-5 on four farms of about 200 acres showed that, taking all the implements on the farms surveyed, the average number of 8-hour days worked per annum was under 15 per machine. Of 153 implements on these farms, 130 worked less than 30 days each per annum. Because of this, the burden of fixed costs—particularly depreciation and interest on capital—which do not vary with the amount of work done, forms a very high proportion of total costs, and the less the annual work output per machine, the heavier this burden becomes per unit of work done. The effect of this factor is easy to see so far as interest on capital is concerned. The annual interest on the capital value of a £1,500 combine at 5 per cent will be £75, whether it handles 50 acres or 150 acres in a year. If it handles 50 acres, the interest charge per acre will be 30s.; if it handles 150 acres, it will be only 10s.

It is perhaps less easy to see the application of this principle to depreciation. Here a great deal depends on the method of calculation. Depreciation arises from two factors—use and age. For every machine there is clearly a maximum working life in terms of work done. One method of calculating depreciation is to estimate the total working life of the machine in hours or acres and to charge against every unit of work a *pro rata* amount of its capital cost. Thus, if it is assumed that the total working life of an 8-ft self-propelled combine, costing £1,500, is 2,000 acres, depreciation would be charged at 15s. per acre. In this example, depreciation would not be treated as a fixed charge. But, deterioration and obsolescence through age are equally important, and except where there is a heavy annual work output, age is more likely to be the governing factor in the life of a machine than actual wear. For example, assuming a working life of 2,000 acres, a combine handling only 50 acres a year should theoretically last 40 years; but in practice this is extremely unlikely; such a machine would generally be replaced long before then. Thus, for most machines, especially on small and medium-sized farms, the age-basis of depreciation is more appropriate and is in fact much more commonly used*. Clearly, on this basis of calculation, depreciation, like interest on capital, is a fixed charge

*The question whether, even on an age basis, depreciation should be calculated each year at a level percentage of the original value or at a percentage of the depreciated value is irrelevant to this discussion.

irrespective of the amount of work done and, like interest, the cost per unit of work tends to rise steeply as the annual work output decreases. In attempting to assess the economy of installing a particular machine on an individual farm, the use of average costs entirely ignores this factor and thus misses out one of the most essential questions.

An illustration of this point is to be found in a recent publication by A. H. Gill on the economy of use of combine harvesters on farms in the South-West*. This showed the following cost per acre figures for 8-ft self-propelled combines at different acreages cut per year (including straw baling):

Acres cut *per year*	Variable Costs† *per acre*	Fixed Costs *per acre*	Total Costs *per acre*
	£ s.	£ s.	£ s.
20	2 11	9 17	12 8
40	2 11	4 18	7 9
60	2 11	3 5	5 16
100	2 11	1 19	4 10

These figures allow for interest on capital at 5 per cent and assume a life of eleven years for the combine and thirteen years for the baler.

On small acreages, these fixed charges constitute the greater proportion of the total and make the cost per acre prohibitive.

To some extent, this difficulty of finding sufficient employment for the more expensive machines on small or medium-sized farms can be alleviated either by sharing arrangements between two or more farmers, or by modifying the farming system to give a longer working season or to increase the total amount of work to be done by the machine. For example, a possible increase in corn acreage or the introduction of an area of herbage seed may be sufficient to tilt the balance in favour of purchasing a combine on a farm relying at present on the binder and threshing machine.

Mechanization and the Economy of the Farm

However, as has been suggested above, many mechanization projects, especially those involving substantial capital expenditure, cannot be judged solely by their effects on the cost of doing a particular job; like most decisions a farmer makes, there may be repercussions throughout the general economy of the farm. Some of these wider economic considerations can best be illustrated by asking a number of questions.

1. *Will the machine make a real saving in labour or only a "paper" saving?* Before this question can be answered, full consideration must

*Some Technical and Economic Aspects of the Combine Harvester, Report No. 81. A. H. Gill *Department of Agricultural Economics*, University of Bristol, 1 Courtenay Park, Newton Abbot. Price 2s. 6d.

†Labour (manual, tractor); repairs, fuel, sacks, and twine.

be given to the point at which additional machinery will have most effect on the organization of labour on the farm. The regular labour requirements of many farms depend on the need for an adequate staff to cope with the busy periods. Machinery which will save labour at those periods is likely to yield the most economic return. There is little point in investing capital in a machine which will save labour only at a slack period. Or again, on a particular farm there may be several peaks and a machine which eliminates only one such peak may still be ineffective until the remaining ones are dealt with. For example, on many East Anglian arable farms the main peak labour periods are the spring and early summer (with corn sowing, potato planting and root hoeing and singling), the corn harvest, and the potato and sugar beet harvests. The introduction of the combine harvester gets rid of one "bottleneck" but does not enable the labour staff to be reduced unless the potato and sugar beet operations can also be mechanized.

2. *Can labour saved by mechanization be used profitably for other purposes?* Particularly on the smaller farms, regular labour tends to be a fixed charge. Where the total staff does not exceed three including the farmer himself (and this is true of the majority of farms in this country) the smallest possible staff reduction (i.e., one man) is obviously a major operation. It is only rarely that mechanization will save sufficient labour to enable staff to be reduced. In general, therefore, the economic advantages of mechanization must be measured in terms of increased output per man rather than lower wage bills; they depend, as often as not, on being able to make productive use of the time saved, either by increasing the size of an existing enterprise or by introducing subsidiary enterprises. This may mean taking concurrent action in other directions to enable the necessary expansion of production to be effected.

As an example of this, experience on a 170-acre Berkshire dairy farm may be quoted. On this farm, a change was made several years ago, from the bucket type of milking plant to a milking parlour. The time saved was carefully recorded and, theoretically, represented $1\frac{1}{4}$d. a gallon on a 35-cow herd. The value of this saving, in wages, was about £175 a year, against which had to be set the interest on capital cost of the new plant. In fact, however, the dairy staff of two remained unchanged, so that there was no actual reduction in wages paid. But this piece of reorganization, combined with a programme of grassland improvement, has enabled the herd to be expanded by 20 cows and has thus played a vital part in increasing the total farm profit by many hundreds of pounds.

3. *Will the mechanization project under consideration necessitate auxiliary machinery or equipment to make it effective, and will the capital be available to cover the whole process?* A common illustration of this type of problem is the purchase of a combine harvester, which often leads to a demand for a pick-up baler to handle the straw and, more often still, to the provision of grain drying and storage facilities.

their findings for analysis. Although, as far as is known, this was the first attempt at co-operation between the N.A.A.S. and the Y.F.C.s on work of this kind, the results show that similar observation projects could be usefully undertaken with benefit to both organizations.

To start with, the Y.F.C. Liaison Officer, Eastern Province, and the County Organizers discussed the project with members of the N.A.A.S. For obvious reasons, it was agreed that those taking part should be members of a milk producer's family, not employees, and that a report form should be prepared by the N.A.A.S. to cover all relevant points on which information was required. The aim was to collect information from up to five farms in each of the larger milk-producing counties in the Province, in order to obtain a fairly wide picture of cowshed cleaning practice. The Report Form (see p. 109) was fairly comprehensive. It emphasized that the information recorded should refer to regular routine practice and, in order to help members to complete the form accurately, they were advised to make daily observations for at least a week. This, of course, would not only help to ensure more accurate information on regular practice, but would also develop the members' powers of observation through a close examination of all details and the possible detection of flaws in the system.

It was left to the County Organizers to get in touch with their own members and to explain the project to them, to see that they fully understood the various items on the Report Form, and to emphasize the need for accuracy. At this stage, too, it was made clear that the farms were to be coded, and that the N.A.A.S. would not know which farms were taking part; the code number merely indicated the county.

The project met with a fairly encouraging response; a total of twenty-three Y.F.C. members willingly joined in the work, realizing that they were playing an important part in a new undertaking.

Analysis of Results

The completed forms were examined and an attempt was made to tabulate the results, to draw attention to the main points thrown up by the survey and, what is most important, to pinpoint weaknesses which should be avoided in any similar future projects.

It was realized from the start that there would be great diversity of practice, but the results indicate that this was much greater than originally thought. A few examples may be cited:

(*a*) *Two* 38-*tie, double-row sheds.* On one farm, two men took 90 minutes to muck out. On the other, two men took 20 minutes.

(*b*) *Two* 28-*tie, double-row sheds.* On one farm, two men took 15 minutes both a.m. and p.m. to muck out, and 1 hour a.m. and 20 minutes p.m. to swill down. On the other farm, one man took 1 hour a.m. and 15 minutes p.m. to muck out, and 15 minutes and 10 minutes respectively to swill down.

Report Form

COWSHED CLEANING

GENERAL NOTES

It is suggested that before completing this form at Section B, daily observations should be made for at least a week, as it cannot be overstressed that the information required to be entered on this form refers to regular routine *practice. The information gained from these observations is necessary in order to compare the cost with that of the dry-cleaning method which is now being tried out. Any additional information which you think would be useful should be included on the back of this form. One form to be completed for each cowshed.*

CODE NUMBER DATE

COUNTY

SECTION A. COWSHED

1. No. of tyings 2. Single or Double Row 3. Cows facing inward or outward
4. Design of shed (a sketch plan with measurements would be helpful)
   (*a*) length (*b*) overall width (*c*) width of feeding passage (if any)
   (*d*) width of dung channel (*e*) width of central or back walk
   (*f*) Is the whole length of shed used for standings?
   (*g*) Are there any passage ways?—if so, state width.

SECTION B. CLEANING PRACTICE

1. Actual time taken to "muck out"
   (*a*) In the morning (*b*) No. of workers
   (*c*) In the evening (*d*) No. of workers
2. What area is actually scrubbed and swilled daily?
   (*a*) Standing (*b*) Dung channel
   (*c*) Centre or rear walk
3. Actual time taken to scrub and swill out
   (*a*) In the morning No. of workers
   (*b*) In the evening No. of workers
4. Are the walls scrubbed daily?
   (*a*) If the answer is "Yes" state (1) actual time taken
   (2) by how many workers
   (*b*) If the answer is "No" state (1) how frequent
   (2) by how many workers
   (3) actual time taken
5. What water is used for swilling down purposes
   (*a*) Private (*b*) Mains (*c*) Rain State if cooling water is saved Yes/No
6. Estimated gallonage of water used daily for swilling down purposes
7. If water is from public mains state cost per 1,000 gallons
8. Is the liquid manure (*a*) conserved; (*b*) used
9. Kind of bedding used (*a*) How much after a.m. cleaning out
   (*b*) How much after p.m. cleaning out

The amount of time and labour used for the different operations showed great variations. At one extreme, three men working a single-row, 14-tie shed took 20 minutes a.m. and 10 minutes p.m. to scrub out, and the same number of men spent 20 minutes a.m. scrubbing the walls. Seven gallons of water per cow were used daily. At the other end of the scale, one man spent 10 minutes morning and evening scrubbing out a double-row, 46-tie shed, using about 10 gallons of water per cow per day. Here the walls were scrubbed monthly only, and two men took an hour over the job.

At only three farms were cowshed walls scrubbed daily. This is an interesting point, because one of the questions so often asked when discussing the dry cleaning method is "but what about the walls?" Further details of frequency of scrubbing walls were as follows:

Frequency of Scrubbing	No. of Producers
Daily	3
Twice-daily	2
Weekly	5
Fortnightly	2
Monthly	3
Every two months	2
Quarterly	2
Yearly	1
When required	1

The best all-round results in milk production are usually obtained where a good routine is practised regularly. Although the information given in the survey shows such tremendous variation, it emphasizes the point that each case must be considered separately as far as the finer details are concerned.

From this limited survey it appears that about 5 gallons of water or less per cow per day is more general than the suggested average of 10 gallons. The following table illustrates this point:

Quantity *gal per cow per day*	No. of Producers
Over 10	1
10	1
9-10	1
8-9	1
7-8	2
6-7	1
5-6	2
4-5	3
3	6
2	1
1	4

One would expect mains supply users to save the cooling water, but this does not seem to be general practice. In fact, eleven of the producers used mains water and five saved the water from cooling: as did eight producers who had private supplies. The average cost of mains water was 2s. 7d. per 1,000 gallons, and in three instances

where the cost was over 3s. per 1,000 gallons, the cooling water was not saved. It seems that rather more water is used where there is a private supply—an average of 5.2 gallons per day compared with 4.3 gallons where mains supplies are available. The differences in water consumption are not really surprising, since on many farms water is used very freely for swilling down, particularly where there is a hose pipe. However, on farms where less water is used, the cowsheds may not be so clean and this point will need careful attention in future surveying.

Liquid manure was saved on nine farms—which is a fairly high proportion—and greater than one might expect. As a result of the observations, one farmer decided in future to save the liquid manure. More facts were needed about the amounts of bedding used; the details supplied were too inadequate for comment.

Conclusions

The results show little uniformity in cowshed cleaning practice—a fact perhaps already widely known but about which little is done. The exercise has revealed several ways of improving the survey method which could well be considered in any future project. There ought to be some assessment of the standard of cleanliness maintained, but since a reasonably uniform assessment would be difficult it might be preferable to use one independent person to do this for the whole sample. On the other hand, the recorder on the farm might, through this work, become conscious of a poor standard of cleanliness and make improvements.

It is generally accepted that a well-designed shed is easier to keep clean, and requires less labour than a shed of inferior design, but even here it must be remembered that much depends on the intelligence and standards of the man doing the job. It would have been useful to know:

(*a*) quality of labour and tools used;
(*b*) suitability of drainage falls, smoothness of walls and condition of floors;
(*c*) amount of muck to be dealt with and distance of muck heap from shed;
(*d*) sundry factors such as weather, soil, approaches to shed, etc.

In addition to providing a means of comparison with the dry cleaning method, the survey has focussed attention on the lack of standard cowshed cleaning practice and the need for more work on the subject.

It has given Y.F.C. members an opportunity of co-operating with the N.A.A.S. in quite a new field, and of taking part in a survey where accurate observations are essential. This co-operation has been extremely valuable, and we are grateful to the Y.F.C.s for their help.

Reviews and Abstracts

Agricultural Pest Assessment

1.—The Problem

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Insect pests have been known throughout history and, for at least 2,500 years, efforts have been made to protect agricultural crops from their attacks. But it was not until about 1860, when arsenical compounds were introduced in America for the control of Colorado beetle, that intensive efforts were made to control crop pests. Major pests were studied, and knowledge of their biology enabled effective control methods to be introduced. At the end of the nineteenth century, attention began to be paid to the economics of pest control, stimulated no doubt by the publication in 1896 of Lodeman's *The Spraying of Plants*[1]—the first of many books on the subject.

During the early years of the present century, pest control became an established part of farming practice and two contrasted attitudes of mind developed. Many of those directly concerned considered that chemicals should not be applied until a pest was present in such large numbers that damage was obvious, whilst others, led by fruit growers on both sides of the Atlantic, argued to an increasing extent that control measures should be applied every season as a routine form of crop insurance in case a pest became abundant. Both implied criticism of economic entomologists, firstly because they were unable to define the conditions under which a given pest started doing economic damage, and secondly because, with a very few exceptions, they were unable to forecast in any given season whether pest density was likely to reach a level at which control would be an economic proposition.

Early Work

In the nineteenth century, a few attempts were made to estimate the damage caused by specific pests. Curtis, in his classical textbook *Farm Insects* [2], quotes losses from some common pests in rather general terms, for example: "During the summer and autumn of 1842 between 500 and 600 acres of turnips were totally destroyed by *Aphis rapae* Curtis near Alnwick and Wooler", whilst Reh [3] mentions estimates of Grape caterpillar damage made in France and Germany in 1891. One of the earliest attempts at a survey on a national scale was that carried out on wireworms by Miss Ormerod for the Royal Agricultural Society in 1882. Data were received from over 100 farmers in England, Scotland, Wales, and the Isle of Man, from which it appeared that cash losses of £2 to £6 per acre were general on infested land [4].

It was not, however, until the early years of the present century that a serious attempt was made to assess a major pest on a routine basis over a large area. The inauguration of the annual Cotton Boll weevil survey by the U.S. Department of Agriculture in 1909 marked a turning point in economic entomology, and provoked an interest in pest surveys which was stimulated further when the outbreak of the first World War emphasized the need for economy in the use of men, machines, and materials in crop protection. In May 1917, the Board of Agriculture circulated the first *Monthly Summary of Insect Pests* which, up to the present day, has given entomologists routine information on pest status in England and Wales. By 1923, the American Association of Economic Entomologists was able to hold a symposium on "Methods of Estimating Insect Abundance and Damage" leading, in 1925, to a report which included methods for assessing the density of, and damage caused by twenty important pests.

The First Serious Assessment

During the period 1925 to 1940, work on pest density and damage continued on a rather small scale, mostly in the U.S.A., where an inherent interest in cash returns provided the stimulus. In 1930, Neiswander and Herr [5] showed by replicated field trials extending over two seasons that the degree of European corn borer damage could be accurately estimated from the average number of larvae per stalk, and in 1938 Hyslop [6] published the results of over ten years' work on "losses occasioned by insects, mites, and ticks in the United States". This was the first serious attempt to assess insect losses anywhere in the world, and drew attention to the need for insurance cover against pest attack. Here it is interesting to note that although no provision was made at that time for estimating insect damage in American crop insurance contracts, neglect by the grower of any essential features of the growing operations normally cancelled the cover. In fact, Flint points out that failure to use insecticides would constitute wilful negligence unless a pest outbreak occurred of which the grower was not warned in advance [7]. A scheme of this type clearly could not operate without a sound warning system based on large-scale field work such as the annual Grasshopper egg surveys which have been carried out in many States since 1931, and which enable adult abundance to be accurately forecast.

Further Investigations

The outbreak of the second World War led to more intensive work on the problem of insect losses. In 1939, the Advisory Entomologists in England and Wales started co-operative work on wireworms which were serious pests on old pastures brought under the plough, whilst Parker, in his 1941 Presidential Address to the American Association of Economic Entomologists, stressed the need for a yearly appraisal of the losses caused by all important pests [8].

Encouraged by the results from the National Wireworm Survey, the Advisory Entomologists in England and Wales agreed to co-operative work on flea beetle damage to brassica crops in 1945. In 1946, dissatisfied with routine estimates of pest status as "above normal", "normal", or "below normal", used regularly in the annual summaries since 1917, they agreed to attempt periodic quantitative assessments of about fifteen important pests [9]. As this work developed, it became necessary to appoint someone at the Plant Pathology Laboratory in Harpenden to develop and co-ordinate survey and experimental work on pest assessment. This post was offered to the writer in 1950 and has led to the formation of a small team of workers with duties comparable to those of the Economic Insect Survey Section set up by the U.S. Department of Agriculture after the first World War. So far as the writer is aware, these are the only two organizations engaged entirely on pest assessment work.

How Accurate are Estimates of Loss?

Annual losses caused by insects to agricultural crops have been estimated recently by Ordish at £50 million in England and Wales [10] and $1,942 million in the U.S.A. [11]. These sums are sufficiently staggering to warrant a careful examination of the foundations upon which they are based.

In the first place, Ordish has taken 1947 as the basis for his annual loss estimates. The unusually severe winter of 1946-47 was followed by a very warm summer, and in many instances pest behaviour differed markedly from normal. From survey data filed at Harpenden it is possible to show that Bean and Cabbage aphids were three times as abundant as they usually are, that Frit and Carrot flies were two-and-a-half times as common, and Cabbage caterpillars were between four and five times as common as in a more normal year. From the available data, it seems that damage by at least eight major pests may have been about three times as severe in 1947 as in a year with less marked extremes of climate. Secondly, as Ordish himself points out, "A number of estimates for certain crops and certain pests have been made by a few workers . . .", and it is these, " . . . with other information, conversations with many colleagues, and our own observations up and down the country . . ." which enabled him to prepare his estimates of overall crop losses. Evidently a few of these estimates were based on properly conducted surveys, but most were little more than informed guesses.

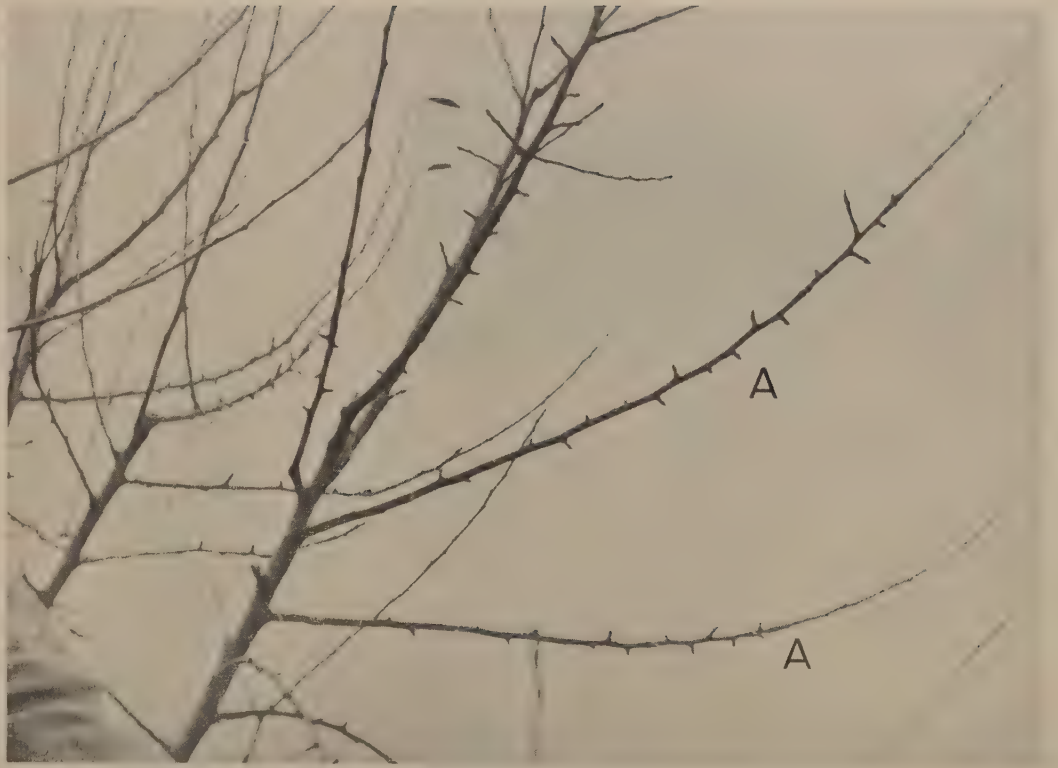
The American estimates are open to similar criticism. It is clearly stated in the introductory chapters to *Losses in Agriculture* that, although based on statistical surveys and records whenever possible, these ". . . were not available for many causes and it has been necessary to rely on judgment estimates made by specialists . . . but, even the information that these specialists have available is limited; consequently the accuracy or reliability of the estimates differs greatly". The American estimate of $1,942 million includes crop losses of $991 million from about 75 pests

Photos: *Rothamsted Experimental Station.*

Proportional counter and electronic equipment used for counting β-emitting isotopes.

Placing radioactive superphosphate and seed with a one-row placement drill.

PLATE I.



Cox tree, showing the production of fruit buds on unpruned laterals at A.

PLATE IV.

for which detailed estimates were made and, on this basis, it was considered that the remaining several thousands of species attacking agricultural crops cause a further loss of $951 million.

Precise and Uniform Observation Needed

From the way in which the British and American estimates of pest losses have been compiled, it might be thought that the problem is more a question of administration than of investigation. It is true that the organization of an insect survey demands the preparation of a suitably stratified random sample of fields as well as co-ordination of the activities of those responsible for the field work. Collating results and preparing estimates of average loss, either in monetary terms or, more appropriately, as acreage equivalents, also demand executive action. But statistical techniques will not provide reliable estimates of pest abundance or damage unless the field surveyors are told precisely what observations to make and how to make them. Unfortunately, through lack of detailed biological knowledge of the pests concerned, a good deal of work has been started in the past on the basis of *ad hoc* methods of doubtful validity, so that many survey estimates are difficult or impossible to interpret in biological or economic terms. One aspect of this question has been noted by Parker [8] who states, ". . . in no instance has any sound, scientific method been employed to determine for the United States as a whole the total annual loss caused by a representative group of our more important pests", in spite of the fact that pest survey work of one type or another had been carried out in the U.S.A. for the previous forty years. Another aspect has been stressed by White [12] in a summary of five years' survey work on Mangold fly in England and Wales. He points out that, although it may be possible to estimate fly density on a crop, the ultimate effect of the pest on yield will depend on the growth stage, size and rate of growth of the plants in relation to the activity of the pest. Similarly, Wright [13] points out that the effect of a given level of Cabbage Root fly infestation on yield varies from season to season and is probably related to the amount of water available in the soil during the growing period of the crop. Straightforward pest density estimates may have little meaning so far as yield of host plants is concerned, and it is necessary to investigate the position for any given pest before large-scale surveys are initiated in an attempt to assess probable yield loss.

Value of Accurate Pest Forecasts

Here it is pertinent to raise the question of the value of estimates of crop losses caused by insects. Survey work is always expensive and often tedious, and although loss estimates are of great value in justifying the allocation of funds for research and in convincing the public that money invested in entomology has not been wasted, the lasting value of the work lies in the better understanding of pest ecology which emerges from a careful study of properly documented field data. It is of the first importance that entomologists should be able to forecast pest outbreaks

in time for preventative measures to be taken, and scarcely less important that they should be able to advise against the use of insecticides when pest densities are not high enough to cause avoidable economic loss. In America, State Agencies and enterprising commercial firms already undertake periodic farm surveys. For a fixed annual fee, individual farmers are informed of the pest situation on each of their crops and given advice on such spraying as is necessary [14].

The Americans, then, have attacked pest assessment problems in two ways: surveys, often based on *ad hoc* methods have been widely used to obtain estimates of pest abundance and damage, and at the same time the possibilities of accurate forecasting have been investigated. A ten-year study, for example, has resulted in a satisfactory method of forecasting European corn borer populations [15], while careful work has enabled Griffiths and Thompson [16] to forecast the egg-laying periods of Florida red scale. In Canada, assessment work has been largely confined to forecasting attacks by forest pests, and important fundamental advances have been made by Wellington and his colleagues [17 and 18].

Little, if any, large-scale quantitative survey work has been done in continental Europe, the general argument being that pest losses are known to be high and that funds are better devoted, therefore, to the fundamental question of forecasting. Climatic variations greatly influence pest densities, and reasonably accurate forecasts of emergence dates and population peaks are often possible in continental areas which have a less variable climate than the British Isles. It is significant, for instance, that at the end of his paper describing the control measures taken against a plague of Wheat Blossom midges in Lower Saxony in 1953 and 1954, Waede [19] strongly recommends the immediate institution of an "alert-service", although it is very doubtful whether high midge densities always cause appreciable economic damage [20]. The position on the Continent has been summarized by Unruh [21] who describes the work of the Plant Protection Office at Bonn and stresses the use made in Germany of Beet aphid forecasts received from Holland and Belgium. French entomologists have also concerned themselves with forecasting rather than estimating damage, the contribution by Regnier and his colleagues [22] providing a good example of the method used for assessing the probable density of cockchafers.

Criteria for Future Surveys

From this summary of work on agricultural pest assessment it is clear that there is very little reliable published information on insect abundance and losses. There is little point in accumulating data which cannot be interpreted, and interpretation demands a critical knowledge of the relationship between pest numbers and crop yields; at present this knowledge exists in very few cases. The main justification for pest survey work must, in the last analysis, rest on the possibility of preventing avoidable loss by the appropriate application of control measures. The

N.A.A.S. Conference of Advisory Entomologists is very much aware of this problem and the impressive contribution made to the subject by the members of the Conference and their colleagues, individually and collectively, since the war will be discussed in a further article.

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Nutrition of Fruit

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Research has established that in addition to carbon, hydrogen and oxygen, higher plants require at least twelve elements for healthy growth and development—nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, boron, copper, zinc and molybdenum. Further work will probably extend this list; there is some evidence already that cobalt and vanadium are necessary.

Essential elements are usually classified into two groups based on the amounts required by the crop. Those taken up in fairly large amounts—nitrogen, phosphorus, potassium, calcium, magnesium and sulphur—are known as major or macro elements, and those required in relatively small quantities—manganese, boron, copper, zinc and molybdenum—are known as minor, trace or micro nutrient elements. This grouping is not based on the relative importance of these elements in plant nutrition: all are equally essential for healthy growth, and if any one of them is not available for the crop, poor growth or even complete failure may result.

In this country, fruit nutrition has presented field problems connected with all the major elements except sulphur. Of the more usual manurial elements, i.e., nitrogen, potassium, phosphorus, and calcium, potassium has proved of outstanding importance for all fruit crops, with nitrogen also coming high on the list. Calcium is much less important, and compared with the requirement of agricultural crops, the phosphorus requirement of fruit has proved to be very low. Disorders caused by deficiencies of minor elements have also proved to be a bigger problem in fruit than in ordinary farm crops, and in fact, deficiencies of all the elements, except molybdenum, have been encountered in the field.

Mineral Deficiency Symptoms

There are various methods of assessing the mineral status of fruit crops, but the most common method, and the only one that can be used in the field, is visual diagnosis. It is based on the fact that most elements produce characteristic deficiency symptoms. Although these symptoms are evident in all parts of the plant, they are most marked and more easily recognized in the leaves.

NITROGEN

Symptoms: Shoot growth restricted and thin; bark shows reddish tints; leaves are small and pale green in colour but later develop characteristic yellow and reddish tints; defoliation is premature; blossom formation becomes much reduced; yields are small; fruit is highly coloured, hard and often sweet, and storage qualities are good.

Excess nitrogen produces very much the reverse effect. Trees become over-vegetative with luxuriant dark green foliage; yield is low and storage qualities are poor.

PHOSPHORUS

This deficiency has been described only in relation to pot culture and experimental plots, and has not been found in the field. Although symptoms of the excessive use of phosphate have not been observed, an excess should be avoided because it may affect the intake of potassium, iron and zinc, and produce deficiency symptoms of these elements.

POTASSIUM

Symptoms: Shoots are rather restricted and thin in the early stages, but as the deficiency becomes more acute extension growth decreases, internodes become short, followed by die-back of the whole branch. The leaves are small, often bluish-green in colour, and may show marginal and intervenal chlorosis, followed by marginal leaf scorch as a characteristic symptom. Defoliation often takes place early in the season; in the early stages trees blossom profusely, but eventually blossom is very much reduced; fruit yield is small and generally of very poor quality.

Excess potash often induces magnesium deficiency. Heavy potash applications in the presence of a good supply of nitrogen produce excessive vigour with large fruits of rather poor quality.

CALCIUM

Symptoms of direct calcium deficiency have never been encountered in the field. This may be because fruit is seldom planted on very acid soil. Under such conditions the trees would make very poor growth and develop mixed deficiency symptoms of most of the major elements with toxic effects of most of the elements like manganese, aluminium and iron, which are common in all crops grown on acid soils.

Excess calcium adversely affects the intake of potassium and magnesium; the status of both these elements in the soil must therefore be carefully watched. The main trouble under these conditions is iron and manganese deficiency.

MAGNESIUM

Shoots in the early stages are very vigorous and accompanied by early defoliation from the base. As the effect progresses and becomes more acute, shoot growth is restricted and finally stops, followed by die-back of shoots and even complete branches. Leaf symptoms are variable but, because of the mobility of magnesium in plants, they always start on the basal leaves of young shoots and develop progressively from the older to the younger leaves. The main leaf symptoms for the various fruits are as follows:

Apple—intervenal chlorosis near the midrib or leaf margins followed by necrosis. When the chlorosis starts in the centre of the leaf a narrow green marginal band may persist for a considerable period.

Pear—blackening followed by necrosis of leaf centre leaving a green margin. In some varieties, however, necrosis starts at the leaf margins.

Plum—central or marginal chlorosis and necrosis with a narrow green margin where necrosis is central.

Black-currant—deep purpling or reddening of the central area leaving a very distinct green margin.

Gooseberry—broad red marginal band fading to yellow.

IRON

This deficiency appears as a chlorosis of the tips of the young shoots. The pattern is very distinctive in the early stages because all the veins form a green network in the chlorotic areas. In very severe cases, when both veins and the intervenal areas become ivory white, whole trees may appear chlorotic. Shoots eventually die-back and whole branches may even die out altogether.

MANGANESE

This deficiency reduces shoot growth and eventually causes die-back in severe cases. Leaves become chlorotic, beginning intervenally near the leaf margins and working inwards towards the midrib. Only the midrib and main lateral veins remain green, thus distinguishing it from iron deficiency.

BORON

It is not certain whether this deficiency has been observed in this country, but a "pimpled" or "measly" condition of the bark has been recorded which is suspected to be due to lack of boron.

COPPER

The first stages appear to be an ill-defined chlorosis of the leaves in the tip region of the young shoot, followed by irregular necrosis, inward rolling, dying and shedding of the leaves. The next stage is the death

of the terminal bud followed by die-back of the shoot from the tips. This condition is often called "Summer Die-back" or "Wither-Tip".

ZINC

Under zinc deficiency conditions, shoot internodes become short and the leaves are very small and narrow. This is often aptly described as "rosette" and "little leaf". The leaves in the early stages may show blotchy intervenal chlorosis and the margins may be wavy in outline. In severe cases shoot and even branch die-back is very marked.

Manuring of Individual Fruit Crops

APPLES

This crop has a very high potash requirement, and generous dressings are required on almost all soils, even where no response to the element is found in ordinary agricultural crops. This is particularly important during the establishment period of an orchard, if the development of the young tree is not to be severely checked. Although some build-up of soil potash takes place during establishment, the need for potash will normally continue throughout the life of the plantation. Any form of potassic fertilizer is suitable for apples and this should be applied during the winter months. A routine dressing of 2 cwt/acre of either sulphate or muriate of potash is usually sufficient, but dressings up to 4 cwt/acre are not excessive during the first few years of establishment, or when the foliage shows severe leaf scorch. Under grass management the need for potash can be very much less; 1 cwt/acre as a routine dressing will probably supply the needs of the crop under these conditions.

The varieties *Cox's Orange Pippin*, *Beauty of Bath*, *Emneth Early*, *Grenadier*, *Allington Pippin* and *Newton Wonder* are highly susceptible to potash deficiency, while *Worcester Pearmain* and *Bramley's Seedling* are much more resistant. The old rootstock MV proved to be very susceptible to potash deficiency; MI, MII, MIV and MVII were grouped as susceptible, whilst MIX and some of the very vigorous stocks were very much less susceptible. The vigorous MXII proved much more susceptible to copper deficiency than MII on copper-deficient soils.

Phosphate requirement of apples is very low and no response to phosphatic fertilizers has been recorded in commercial orchards. Nevertheless, as a precautionary measure a dressing of 3 to 4 cwt/acre of superphosphate is generally recommended every three or four years. This is particularly necessary in grass orchards if the grass-clover sward is to be maintained in good condition.

It is not easy to specify the amount of nitrogen necessary for apple crops, since the dressing should be adjusted every year according to the needs of particular varieties, the condition of the trees and the cultural system practised. In general, culinary varieties should receive higher dressings than dessert varieties. Under arable conditions, dressings of 4 to 5 cwt/acre of sulphate of ammonia or its equivalent are normally sufficient, whilst under grass culture the quantity can be increased to

6 or 8 cwt/acre. To avoid severe nitrogen deficiency when grassing down an orchard, an initial dressing of 10 cwt/acre is often applied. It is often said that the extra nitrogen may be better applied in the form of urea as a foliage spray. This supposition is difficult to understand when one considers how quickly crops respond to a normal soil application.

Apples have a high magnesium requirement, especially on light soils, and a routine treatment must often be adopted which will vary according to the severity of the trouble, the potash status and the degree of acidity in the soil. For mild symptoms, one or two spray treatments with 2 per cent magnesium sulphate may alleviate the trouble; for more acute deficiency three to five treatments, at fortnightly intervals will be necessary. This treatment may have to be supplemented by an annual soil treatment with about 4 cwt/acre of magnesium sulphate. If the soil is acid and needs liming, an application of high grade magnesian limestone is recommended, in fact this form of lime should always be applied in preference to calcium limestone, since it supplies both calcium and magnesium.

PEARS

Manuring of pears should be similar to that of apples, except that they can stand a more liberal dressing of nitrogen and are less susceptible to potash deficiency. Pears also benefit from occasional dressings of dung and bulky organic manures like shoddy.

For routine purposes, dressings of nitrogen, phosphate and potash in amounts recommended for apples are suitable for pears, but using the higher rates of nitrogen and a slightly lower rate for potash. Dressings up to 15 tons of farmyard manure or 2 tons per acre of shoddy can be safely applied.

PLUMS

Up to the present, plums have been grown mostly under arable culture, thus ensuring high nitrogen condition and maximum moisture during cropping. In recent years, many plum plantations have been grassed down, and although some nitrogen deficiency has occurred, even with heavy nitrogen applications, there is no doubt that proper control of the grass gets over this trouble.

As well as needing from 4 to 8 cwt/acre of sulphate of ammonia or its equivalent, plums benefit very considerably from occasional heavy applications of farmyard manure or any other form of bulky organic manure available. Phosphorus and potassium requirements of plums have not been clearly established, but observations seem to show that the phosphate requirement may be slightly higher and the potassium slightly lower than for apples. *Purple Pershore* and *Blaisdon Red* are exceptional regarding their potassium requirement, both being very highly susceptible to deficiency of this element.

Plums are often planted on calcareous clays and chalky boulder clays. This choice is partly due to the old idea that stone fruits require large

amounts of calcium for satisfactory development. The frequent occurrence of severe iron deficiency in plum plantations is doubtless due to excess lime in the soil and not, as is often stated, to any inherent susceptibility of the plum to this deficiency.

CHERRIES

Sweet cherries are grown almost entirely in grass orchards heavily stocked with sheep to maintain a closely grazed sward. Cherry orchards in general are located on deep fertile loams with a high all-round fertility status. The main treatment has been fairly heavy applications of phosphatic fertilizers to maintain a good productive sward, to pass on the maximum benefit to the trees via the grazing animals. This system of management is slowly being replaced by a grass mowing system now in common practice for apples, and cherry manurial practices will have to be on similar lines to those advised for dessert apples, using the lower levels recommended for nitrogen and possibly slightly lower levels for potassium.

Sweet cherries are susceptible to manganese deficiency when planted on soil with a high lime status, and it is common to find severe manganese deficiency in cherry orchards on soils where other tree fruits would develop iron deficiency.

The manurial requirements of sour cherries are similar to those of plums and the same programme should be followed.

BLACK CURRANTS

These respond well to very generous manuring; more so, perhaps, than any other fruit crop. They are very responsive to good-quality farmyard manure and applications of 15-20 tons/acre seem to be sufficient to grow heavy crops without the addition of any artificials. Experiments have shown that the crop responds to all three elements, nitrogen, phosphorus and potassium, and that the highest yields of good-quality fruit can best be obtained with a base dressing of bulky organics supplemented by fertilizers, especially nitrogen. A suitable fertilizer treatment per acre, where bulky organics are not available, would be 6 cwt sulphate of ammonia, 3 to 4 cwt superphosphate and 2 cwt sulphate or muriate of potash. When farmyard manure is available both the nitrogen and potash applications could be reduced.

GOOSEBERRIES

Of all fruits, gooseberries are about the most susceptible to potassium deficiency, and experiments have shown that they also respond to moderate amounts of nitrogen and phosphorus. They respond well to farmyard manure and 10 tons/acre, supplemented with a light dressing of fertilizers should ensure a good crop. As gooseberries may be susceptible to chloride injury, sulphate rather than muriate of potash should be used. If dung is not available, a good mixture of fertilizers per acre would be 2 to 3 cwt sulphate of ammonia, 2 to 3 cwt superphosphate and 2 cwt of sulphate of potash.

Lucerne Management

Lucerne is now being successfully grown under a very wide range of conditions in this country. Its drought-resistant properties were very much in evidence during 1955, and as the possibilities of this high-yielding legume gradually become recognized, so the acreage of lucerne leys increases. However, there are many aspects of its culture which require further investigation, and new evidence concerning this crop is continually being produced by current research.

Soil Conditions and Fertilizer

The root and nodule development of lucerne during three years after seeding was studied on different soil types in America by Fox and Lipps [1]. On acid soils, liming had a marked effect on root growth during the first year, and resulted in roots penetrating to a depth of over five feet, while on comparable unlimed soils, the roots only penetrated to three feet. There were indications that nodulation was reduced, and fibrous root growth poorer, in the soil regions where there appeared to be a deficiency of either calcium, magnesium or phosphorus. Herbage yields were considerably lower from the unlimed plots, and not until the end of the third year was the herbage produced comparable with that from the limed area.

Lucerne normally derives its nitrogen supply from nodule bacteria. It might be supposed that fertilizer nitrogen, if added early or late in the season when the nitrifying bacteria are relatively inactive, might provide additional growth, particularly from any companion grasses. However, the more vigorous growth from the grass might eventually reduce the proportion of lucerne in the sward. Alder [2] investigated the effect of 2 and 4 cwt of "Nitro-Chalk" per acre (applied either in September or late February), on a lucerne/Italian ryegrass ley. The experiment lasted two years. "Nitro-Chalk" increased yields in both seasons, and the best response was to spring nitrogen. In the first year, the nitrogen apparently increased the yields of both grass and lucerne, but in the second season the yield of lucerne was depressed by nitrogen, particularly when applied in the spring at 4 cwt per acre. This depression was attributed to increased competition from the grass. In the second season the total yield was lower at the 4 cwt than at the 2 cwt level.

Ridgman *et al.* [3] studied the influence of three years' light nitrogenous dressings on a lucerne/cocksfoot ley grown on gault clay in Cambridgeshire. Each application was at the rate of 1 cwt of sulphate of ammonia per acre, and the times of application were at the end of February, after the first harvest (June) and after the second harvest (August). All combinations of nitrogen or no nitrogen with the three application dates were tested. Throughout the three harvest years, the treatments caused no marked changes in the botanical composition. Increased yields of grass usually followed nitrogen application, but it had no significant effect on the lucerne yield. The February application

produced the greatest increase in the yield of grass and total herbage yield; the average increase from this dressing being about 3 cwt of dry matter per acre. The June nitrogen also produced a significant increase in total yield of 2 cwt per acre. It was suggested that the increased growth of grass without a corresponding reduction in the lucerne was due to the low rates of nitrogen applied, and to the fact that the lucerne was always at the late bud or flower stage before cutting.

The effect and diagnosis of boron deficiency in lucerne is discussed in some detail by Lachance and Ouellette [4]. Histological examination of leaves and stems showed that boron deficiency was characterized by abnormalities of the vascular bundles, and was first noticeable near the growing tips. The abnormalities noted under the microscope are thought to be specific to boron deficiency and constitute a valid criterion for the diagnosis of this trouble whenever visual symptoms are insufficient. The severity of the disturbances apparently depends upon two factors—the amount of boron available and the age of the plant. In the early stages of growth, plants receiving less than the optimum may not show symptoms but these may become evident as the plants grow older. The same authors [5] compared visual symptoms of boron deficiency with histological studies; the two methods of identification only differed four times in 143 cases. In addition, plant tissue and soil samples were analysed for boron. There was a fairly distinct level of boron in the plant tissue above which no plant exhibited symptoms of deficiency. The distinction was not so clearly defined in the soil analyses, and it appeared that plant tissue tests offered a more reliable criterion than did soil analysis for deciding whether the boron supply was sufficient.

Time of Defoliation

The importance of the date of cutting lucerne in the autumn was well demonstrated by Jones [6]. Spaced lucerne plants were cut either in late August, late September or late October and compared with uncut controls. Any of the cutting treatments reduced the weight of tap-root, quantity of food reserves and the growth of herbage in the following spring. The most adverse treatment was the September cut which reduced herbage yields in the following spring by 50 per cent. This was probably because after cutting in September fresh herbage was produced at the expense of reserves, without sufficient time being available for replenishment. Plants cut in August had a better chance to synthesize replacements, while those cut in October produced little or no fresh growth.

Further evidence on the effect of the autumn defoliation date was presented by Barker *et al.* [7]. A cocksfoot/lucerne ley was defoliated either at the end of September, or at the end of October, for several years. Although the two treatments had no marked consistent effect on the total yield of herbage in the following season, they had a marked effect on the individual constituents. The earlier cutting increased the yield of grass in the following season, whilst the October cutting gave

higher yields of lucerne and nitrogen and in the following spring a greater proportion of lucerne in the herbage. These authors also concluded that the September defoliation had an adverse effect on the food reserves of lucerne. Finally they considered that although the later defoliation left the crop without any protective covering during the winter, this was not important for the winter survival or future productivity of lucerne under East Anglian conditions.

Not only the last defoliation of the year, but also the first cutting date in the spring is important for the maintenance of vigour in lucerne. Jones [8], Green [9] and Green and Jones [10], all indicated that once the growth of lucerne had commenced in the spring, grazing or cutting before the end of May tended to be detrimental to lucerne. Ideally, lucerne should be cut in the spring at flower-bud formation; this should be followed by two or three more cuts, and one or more of the rest periods should be not less than eight weeks. It was also considered that the length of the last interval before cutting in the autumn was just as important as the actual cutting date; i.e., the plant needs adequate time to build up its reserves during the last rest period. The importance of the first cutting date was also demonstrated by Dent [11] in East Anglia. Lucerne was cut in the spring at various stages from the time a height of 12 in. had been attained to early flowering (mid-season cuts were at the early flower stage). By taking the first cut at the early bud stage in 1953, the optimum yield for the year of dry matter and crude protein was obtained—10,600 and 2,080 lb respectively—compared with a dry matter yield of 8,800 and a protein yield of 1,620 obtained by taking the first cut when the lucerne was 12 to 14 in. high. After the appearance of the first buds, the fibre content increased rapidly but there was very little further increase in the total protein yield, and the percentage of protein in the herbage fell considerably.

Grazing

Lucerne can produce abundant fodder during the dry periods of mid-summer. It is sometimes said that lucerne will not withstand grazing and that this handicaps the general usefulness of the crop. There is, however, evidence showing that lucerne can be successfully grazed in mid-summer without any damage. In one experiment, the second crop of lucerne in each year was either cut or grazed in July [7]. Each of these treatments was then either cut or grazed in the autumn. The method of defoliation had very little permanent effect on either the total yield or composition of the ley, although occasionally the yield of grass was affected in the next crop.

Presumably one of the reasons why the grazing had such a slight effect on the lucerne was that the periods of grazing were short, and were followed by long rest periods. These results are confirmed by Green and Davis [12]. Cattle on the lias clays of Warwickshire had valuable summer grazing from various lucerne/grass mixtures. Provided the grazing periods were short and not too frequent, lucerne recovered normally, and a

good balance of grass and clover was maintained in the mixture. The same authors and Jones [8] also showed the beneficial effects of grazing lucerne/grass swards in the late autumn and winter after active growth had ceased. This treatment gave useful out-of-season keep, and effectively checked the grass so that in subsequent seasons a good balance of lucerne was maintained. Winter grazing should be completed before lucerne commences growth in the spring.

Because lucerne is not damaged by winter grazing it was found to be a valuable legume for including in mixtures intended for winter keep. Hughes [13 and 14] obtained excellent results by sowing alternate wide drills of grass and legume 12 in. apart. When these drills were top-dressed with "Nitro-Chalk" and then rested during the autumn, they provided a good growth of herbage for winter grazing. In addition, they were capable of providing two or three crops during the following spring and summer for grazing or conservation. Two of the most successful companion grasses in this system were cocksfoot and tall fescue. (A sward of tall fescue dressed with 4 cwt of "Nitro-Chalk" per acre in August, 1953, had produced 3,300 lb of dry matter per acre for grazing by January, 1954.) The lucerne remains extremely vigorous under this system, and it seems that the wide drills remove the competitive effect of grass and allow a greater latitude in the management of a grass/lucerne ley.

Different methods of utilizing lucerne by beef stores were investigated by Meyer *et al.* [15]. The methods compared were five-day rotational grazing; strip-grazing (moving the fence once or twice daily); hay; and soiling (both the hay and soilage were fed twice daily). The beef production per acre from the different systems was 690, 740, 860 and 1,080 lb per acre respectively. Thus, soiling produced considerably more per acre than any other system. The soilage cattle consumed more dry matter per day than either the strip- or rotationally-grazed cattle. Despite this, the liveweight gain per head per day was the same on both grazing treatments and soilage. Presumably this was because of the selective grazing by cattle on pasture.

Successful culture of lucerne is thus dependent upon two important points: firstly, it is a crop which produces a large bulk of herbage and must therefore be well supplied with nutrients; secondly, its production of fresh herbage after defoliation is at the expense of food reserves, and in order to maintain the vigour of the plant, it is necessary to allow adequate rest periods after cutting or grazing.

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H.K.B.

Poultry Husbandry

Rapid development of table poultry production in this country, and particularly the increased production of "broilers", has led to price levels tending to become lower. Broiler growers generally realize that further economical increases in output must depend on the price of broilers competing with the price of red meat. In consequence, any methods of reducing production costs—however small—are sought for with enthusiasm. It is generally recognized that strains of broilers specially bred for the meat market are needed, but since this process is relatively slow, greater immediate attention is being paid to the improved feeding of young table chicken.

Fat and Methionine Supplementation

The increased use of detergents has reduced the demand for soap; consequently, new uses for fat are being investigated. One which has aroused great interest has been the use of fat in high-energy poultry diets, and much literature on the subject has now been published. This addition has, however, brought in its train special problems; the resulting high-energy diet increases the need for other nutrients if the diet is to be efficiently and economically utilized. One aspect of the problem is dealt with in "The Concomitant Use of Fat and Methionine in Broiler Diets" by H. R. Rosenberg, J. T. Baldini, M. L. Sunde, H. R. Bird and T. D. Runnels (*Poult. Sci.* 1955, **34**, 1308-13). Using a corn/soya bean meal, these workers found that after adding 0.05 per cent DL methionine to the ration there was a small improvement of the growth rate of birds up to ten weeks. The addition of 3-6 per cent fat to the basic diet brought about a much greater increase, and the food conversion rate was substantially improved. But when both fat and methionine supplements were used, an even greater improvement was recorded. Much the same conclusion is made in a paper on "The Effect of Productive Energy Level of the Diet on the Methionine Requirement of the Chick", by J. T. Baldini and H. R. Rosenberg (*ibid.* **34**, 1301-7). They found that the methionine requirement expressed as a percentage of the total diet increased in proportion to the productive energy level of the diet. They consider that the methionine requirement as a percentage of the total diet can be estimated at any productive energy level between 800 and 1,000 calories per lb of food, and suggest that this concept can be applied to most of the nutrient requirements of the chick.

Effects of Adding Methionine to the Ration

One result of methionine supplementation which will be of interest to broiler growers and also to commercial egg suppliers is its apparent influence on cannibalism and feather picking. Both these vices occasionally result in heavy losses under intensive management on the deep litter system. In a contribution entitled "Cannibalism, Pick-outs and Methionine" by W. M. Neal (*ibid.* **35**, 10-3) the author presents evidence showing that methionine supplementation tended to suppress feather picking and cannibalism. These vices remained suppressed for about the same time that the supplementation maintained an increased physiological level of this nutrient. The level of supplementation was 1 oz of commercial DL methionine per cwt of ration, fed for forty-eight hours. The total level of methionine was only 0.3 per cent which does not greatly differ from the N.R.C. recommendation of 0.28 per cent. It is suggested that the small addition over the recommended level for egg production is fully justified, since feather picking and cannibalism may destroy profits, even though egg production reaches profitable levels. The author comments briefly on various explanations of feather picking, such as overcrowding, and points out that his evidence contradicts these common hypotheses. In support of his view, he draws

attention to the improvement sometimes observed following oat feeding. This action would reduce the energy content of the diet, thus narrowing the methionine : energy ratio, and Baldini and Rosenberg's conclusions (*op. cit.*) on this ratio have already been noted.

Antibiotics

In this country, broiler growers use antibiotics fairly extensively. Doubts have been expressed whether we can expect the same improvements experienced in North America as our broiler industry becomes increasingly established. On this point a paper on "Further Evidence on the Relation of Coliforms to the Growth Response of Chicks to Antibiotics" by M. M. Hauser, G. W. Anderson, W. F. Pepper and S. J. Slinger (*Poult. Sci.*, 1955, **35,** 27-36) presents data that when chicks housed in clean premises received an antibiotic (chloromycetin), maximum growth response was delayed until the last few days of the 17-day experimental period and was accompanied by an increase in intestinal coliforms. As the level of the antibiotic was increased from 10 to 200 p.p.m., the feed conversion rate was progressively improved and lactobacilli counts reduced. In other experimental work described by these workers, the use of various antibiotics with chicks in badly contaminated housing led to improved growth rates in the early stages of their lives, and these improvements were accompanied by increases in intestinal coliforms. These results would indicate that the growth response associated with the feeding of antibiotics to broilers and other young growing birds is related to an increase in the intestinal coliform population. The authors conclude with the suggestion that the variations reported in the time and extent of the growth-promoting effect of antibiotics may well be the result of differences in the response of coliform bacteria to antibiotic stimulation.

Broiler Strains and Environment

It has been stated that the expansion of this country's broiler industry must be dependent on stock specially bred for this market. Although this view is widely accepted, the suggestion has been put forward that chicks specially bred for the broiler market in one part of the country may not show the same superiority if reared in a markedly different environment. This problem was recently investigated by Canadian workers, and in a paper on "Environment and Poultry Breeding Problems" by E. S. Merritt and R. S. Gowe (*Canadian J. of Agric. Sci.*, 1956, **36,** 72-80) the authors give an account of the performance of a number of samples of broiler strains reared at three farms under uniform diet and management routine, but with substantially differing environment. The authors found that with all the economic traits studied, the variances associated with locations were less than those associated with strains. There would seem, therefore, to be no point in breeding strains of table chicken for any particular environment.

R.C.

Provincial Notes

Cereal Demonstrations in Cambridgeshire

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FOUR OR FIVE cereal variety trials have been carried out in Cambridgeshire each year since the early days of the N.A.A.S. Whenever they were situated in roadside fields, interest was shown by local farmers, and casual enquiries would reach District Advisory Officers about the varieties and the results. In 1951, one block of the experiment had small descriptive notice boards beside each variety, so that farmers who chose to stop could examine the varieties being grown. An attempt was also made that year to place all trials on main roads, the attention of passers-by being attracted, not only by small notices beside the individual varieties, but also by a large notice board measuring 4 ft 6 in. by 2 ft 6 in. The same procedure was adopted in 1952, and judging from the footpaths worn in the grass verge and along the edge of the crop, there were numerous visitors.

In 1953, the programme of using trials for demonstrations was carefully reviewed because of the availability of funds from the Mutual Security Agency. For one thing, the comparatively low level of manuring then used for N.A.A.S./N.I.A.B. variety trials often made it obvious that the whole trial area would have a lower yield than the surrounding field crop. Also, it was often difficult to find a site with easy access to the road, yet clear of gateways, trees, etc. Furthermore, to use an experiment designed to discover fresh information as a means of explaining known techniques was a doubtful expedient. A programme of roadside demonstration plots quite unconnected with experimental work was therefore planned. Leaflets were to be available on the site explaining the plots, and referring to the experimental work supporting the points demonstrated.

Cereals an Obvious Choice for Cambridgeshire

Since half the farming income of the county is obtained from cereals, it was decided to confine the demonstrations to these crops, concentrating on variety and nitrogenous manuring—the two factors which influence profits most. Recent surveys of fertilizer practice in the eastern counties had shown that manuring of arable crops was usually adequate, except for nitrogen on cereals. By applying 1954 prices to the experimental evidence gathered by Crowther and Yates in 1940, it was evident that nitrogen applications to cereals should be approximately doubled. Until recent years, the full response to nitrogenous manuring at optimum levels had not been achieved, because lodging intervened at

only moderate rates of nitrogen. Improvements in modern cereal varieties, especially wheat, have resulted in profitable responses from increased applications of nitrogen, but although the new varieties had been widely adopted, the old level of nitrogenous manuring persisted. It was decided, therefore, to demonstrate the profitable use of nitrogen in relation to modern varieties, a subject which could be effectively demonstrated by plots.

Layout, Treatment and Publicity

In preparation for the summer of 1954, twelve sites were selected on main roads, and by co-operation with the farmers concerned, six sites were sown with six varieties of winter wheat, three sites with three varieties of winter oats, and three sites with six varieties of spring barley. The varieties chosen were mainly those likely to be most profitable in the county, together with one or two others, which were still being grown for some obscure reason. By contrasting one group with the other it was hoped that the demonstration would be more effective. To ensure a reasonable response to sulphate of ammonia that would be acceptable to most farmers, sites were selected on fields not above the general level of fertility.

The same varieties were sown at each centre, in strips of four drill-widths each (about 12 yards) and from 2-4 chains long. In the spring, the autumn-sown crops were top dressed with four different rates of sulphate of ammonia across the varieties. Similar treatment was given to the spring barley as soon as it was through the ground. For wheat, rates of top dressing with sulphate of ammonia were 0, 2, 4 and 6 cwt/acre, and for winter oats and spring barley, 0, $1\frac{1}{2}$, 3 and $4\frac{1}{2}$ cwt/acre. Pathways between treatments were cut 3 ft wide with an auto-scythe so that visitors could pass along; two main gangways across the plots were sufficient. The plots were not harvested for information on yield.

Attractively printed leaflets were placed in carefully made boxes holding 25-50 each. The boxes were refilled frequently, the number of leaflets used being noted. At the end of the season 1,400 leaflets had been removed between the end of June and the end of August, when the plots were harvested. Another 300 people saw the plots on organized farm walks. Fieldwork amounted to about three days per centre for each District Advisory Officer concerned. During the autumn the demand from farmers for a summary of the effects observed on the plots became insistent, and a report was published which, although it could only in part consist of information from the demonstration plots, nevertheless provided an excellent opportunity of presenting the latest information from trials and experiments in the Province.

The 1955 Programme

A similar programme was undertaken for 1955, the only alteration being the substitution of three spring wheat demonstrations for the winter oat series. Each individual treatment was standardized at a

half chain square, the whole just exceeding half an acre. New leaflets were prepared and placed in the boxes: 700 were removed by casual visitors; 340 farmers were conducted round the plots at organized farm walks. The fewer casual visitors were probably partly a result of the 1955 sites being less favourably placed.

Under four different fertilizer treatments, the eighteen cereal varieties gave many interesting reactions. These were of sufficient interest for advisory and research workers to arrange a special tour of the centres by the staff from the National Institute of Agricultural Botany, the Plant Breeding Institute, Cambridge, and the School of Agriculture, Cambridge University, which resulted in a valuable exchange of views. Points of special interest were the differential varietal resistance to eyespot, the earliest incidence of black rust on spring wheat reported in the Province, and the apparent lower response to sulphate of ammonia on chalk soils. The last observation may induce future investigational work.

An additional feature in 1955 was the provision of a tear-off slip on the leaflets, which could be completed by the visitor if he required further information, and a report on development work on cereals. The slips could either be left in the box or posted to the County Agricultural Officer. Seventy-four slips were returned, mostly by post; twenty-eight of these came from visitors living in thirteen different counties, including Yorkshire, Northumberland, Oxfordshire, Herefordshire and Somerset, whilst from even further afield, two requests were received from Swedish visitors and one each from New Zealand and the Irish Republic.

Conclusions

Choice of sites is all important—it is obvious that they must be on roads carrying a good volume of local traffic; probably the use of less suitable sites in 1955 resulted in fewer visitors. The ideal site is easily visible for some distance along the road, is not near corners or cross-roads where the driver's attention would be fully concentrated on the road, and is situated where it is easy to pull a car off the road.

Widespread interest in the two seasons' work shows that the demonstrations have been well worth while, especially when it is remembered that more than half the farming profit in the county comes from cereals, and that the crop in 1955 was worth about £5,000,000.

The demonstrations brought up-to-date advice on cereal production to far more farmers in the county than could ever have been visited by District Advisory Officers. Attendance figures averaged over 1,300 a year, and in Cambridgeshire there are 1,000 farmers with holdings exceeding 50 acres who farm 90 per cent of the county's land. During the year, each District Advisory Officer deals with forty requests for advice on varieties and manuring of cereals. Even if a visit by a farmer to the plots were only one-third as effective as individual, but non-visual, advice on his own farm, something like the same effect could

only have been achieved by increasing each District Advisory Officer's visits on this subject nearly threefold—an increase of 25 per cent of his total farm visits.

Light Pruning of Apples in South-East England

W. G. KENT

National Agricultural Advisory Service, South-Eastern Province

DURING the writer's early years as Advisory Officer in commercial fruit growing in Kent, the general concept of a bush apple tree was a tree with a number of permanent branches, each furnished with fruit spurs that would bear fruits close to the branch. The number of branches was often limited to an arbitrarily fixed number, and the leading shoot of each branch was shortened annually to induce all buds left on it to grow into spurs or shoots and so avoid bare lengths of wood. Shoots not selected as leaders to continue existing branches or start new ones were completely cut out if they were to compete with the leaders. The others were shortened to two or three inches, so that any fruit buds formed later would be near the main branches. Only a few, quite weak laterals were left unshortened.

Trees of medium or less vigour responded fairly well to these treatments, but vigorous trees produced too much shoot growth, and cropping was greatly delayed or even prevented. Advances in knowledge of the factors affecting fruit tree nutrition, and the siting of new orchards on the better soils, led to a greater proportion of vigorous young trees. At the same time, the leading shoots of standard and half-standard apple trees on fruit farms were not being shortened, and other growths were only removed or shortened when overcrowding the branch system. It became evident, with the variety Laxton's Superb in particular, that trees pruned lightly on this system cropped earlier in life and more heavily, especially on unpruned laterals, than on more closely pruned bush trees—even if these were on more precocious rootstocks. This led the writer to recommend that many laterals be left unpruned on vigorous young trees, standard or bush alike.

Development of the Renewal System

Late in 1935, C. R. Thompson arrived in Kent as the writer's assistant from Long Ashton Research Station, where for eight years he had carried out and recorded treatments in a tree shaping and pruning trial conducted by Dr. Swarbrick. An early task before us was to conduct classes in pruning in the Paddock Wood and Ash districts of the county. Thus it became necessary to sort out our ideas and to express them intelligibly to our pupils and to growers generally.

It was soon decided that what was desirable was to shorten only enough laterals to ensure an adequate supply of new ones in the coming year, and to leave the rest to crop as quickly as possible. It became evident in following years that the essential points for consideration were the treatment of leaders to produce the required number of new branches and laterals, the treatment of one-, two- and three-year-old laterals and of spur-systems, the spacing of branches, and the structure of the main branch system to support the weight of heavy crops.

Although no single new practice was involved, there was a need for a written explanation of the relationship between the various details of treatment over a period of years, and the idea of the system as a whole. Thompson first attempted this in a series of articles in the *Fruit Grower* and later as a booklet, *Modern Apple Tree Pruning*, followed by a more ambitious publication in book form.

The main concept was of a flexible system that could be applied as required to trees of any degree of vigour, that could build a good branch structure, induce early cropping, and yet maintain continuity of tree vigour, development and cropping. Instead of retaining a complete permanent branch system with ageing and weakening parts, the tree could be renewed by developing new leaders from suitable positions and removing the oldest cropping parts. Thompson therefore devised the term "renewal" for the pruning system now so widely practised.

Classes, lectures, demonstrations and advisory visits helped to spread knowledge and practice of the renewal system before the 1939 war. We were encouraged by the record of a West Kent orchard of Cox and Worcester planted as maiden trees at 193 per acre in March, 1936, and pruned under Thompson's guidance. In autumn, 1939, the trees yielded 180 bushels of fruit per acre—nearly a bushel per tree within four years of planting. The treatment was not detrimental to tree development, for the orchard has continued in first-class condition up to the present time.

With the outbreak of war, it was all the more necessary to encourage increased production. Nearly two thousand leaflets on pruning were distributed to Kentish growers by the Kent War Agricultural Executive Committee, and demonstrations and lectures continued. It was found that many Land Army girls working on fruit farms grasped the main essentials of renewal pruning very quickly and proved very useful workers if properly briefed. Thompson himself did much of this briefing. Resistance to the new ideas came most often from older men steeped in the tradition of spur pruning, which is more nearly a mechanical operation.

Interest in renewal pruning in Kent grew rapidly—300 growers and fruitmen attended the first large-scale pruning demonstration after the war. There was, unfortunately, a great shortage of demonstrators and teachers which was accentuated by Thompson's departure to commercial fruit growing.

The setting up of the N.A.A.S. in 1946 gave great impetus to the spread of the new methods, and made it possible to bring a number of

experienced advisory officers to Kent for courses in renewal pruning. These officers at once recognized the merits of the system, rapidly assimilated the underlying principles, and were eager to teach and demonstrate it in their Provinces and counties. As a result of their efforts, it has become the standard pruning system of the fruit farmer, and a very high percentage of the younger orchards in the main fruit areas of the country is now being pruned on renewal lines.

Building the Tree Framework

Renewal pruning is a sufficiently flexible system to apply to any apple tree, but the young tree which will give the best results quickly is one with wide-angled primary branches disposed evenly over a length of central stem. Forking at narrow angles often leads to branches splitting apart, especially when pruning is light.

In the first season, after cutting back the maiden tree, about three to five primary branches can be obtained, over a length of central stem of from 6-9 in. The more erect lateral shoots should be cut clean out in favour of the wider-angled ones; or, better still, rubbed off in the growing season when the shoots are 2 or 3 in. long. The retention of a centrally placed leader, cut back to about 12 in. in the next winter, induces a further supply of primary branches, now spread over a length of 18 to 21 in. of central stem. This usually gives sufficient primary branches for a bush tree.

The number of branches suggested for retention in a young tree with a spread of up to 6 ft is from three to four for each ft in diameter of branch spread, spaced as evenly as possible. The "open vase"-shaped tree with branches intended to be permanent is totally superseded, since lightly pruned branches naturally lean outwards more and more so that they ultimately need replacement by branches more centrally placed.

Except on very vigorous trees, it is necessary to shorten the leading new growth of existing branches by one third to one half in order to secure new branches and lateral shoots. The point at which a leading shoot is shortened, or "tipped", should not be less than a foot from any adjacent leader. Although one side of the tree should balance with the opposite side, leaders should not be cut all at the same level. They should be shortened *more* than average, and *less* than average, alternately throughout the tree.

Upright shoots, especially those likely to compete as leaders with those selected, and laterals crossing or crowding the tree, should be removed completely. Well-placed lateral shoots, those in full light, and especially those with a wide-angled outer direction, should be left unpruned. These form fruit buds in the following summer and can crop in one more season. Thus the young bush apple tree may begin to bear appreciably in its fourth, or more usually its fifth summer.

Pruning Mature Trees

In the pruning of older trees, the first operation is the complete removal of any branches that crowd the tree or impede grass-cutting or soil cultivation. No two branches which are less than 18 in. apart should run parallel if the laterals of one crowd those of the other and deprive both of enough light and air. It is better to leave plenty of laterals unpruned on one branch and entirely remove a competitive branch, rather than to cut back the laterals closely on both.

Branches that are too tall or spread too widely should be cut back to a suitably placed lateral branch.

LEADERS

Very vigorous trees may produce enough new shoots to increase the branch system and enough new laterals without any tipping.

Less vigorous trees may produce fruit buds on their leaders and few or no laterals if they are not leader-tipped. The vigour of the tree should indicate the proportion of leader to be removed; this is about one third for moderately vigorous trees, though some leaders may be left untipped.

Weakly trees should be invigorated by cultural methods, including manuring, rather than by pruning away most of the new wood. It may be desirable to reduce the burden of too much blossom with too little shoot and leaf by cutting or rubbing out a considerable proportion of the fruit-buds.

Since lightly-pruned branches widen readily under the weight of a crop, leader treatment should cease at their extremities and be transferred to suitably placed laterals arising from their inner or upper sides. It is usually possible to anticipate the need for such "renewal" branches and begin leader treatment on selected inner laterals before widening of branches makes the centre of the tree too open.

At this stage, leaders of upright branches above a height of about 8 ft should not be tipped, but the branches should be shortened to outward-pointing laterals. Thus, in a few years all leader tipping will occur well within the periphery of the branch system.

LATERALS

Some one-year laterals—preferably those of horizontal tendency and in full light—should be left full length each year to form fruit buds in their second season and bear fruit in their third. Others should be cut back to about 2 in. to induce them to produce new shoots rather than fruit buds. A larger proportion of laterals should be left unpruned on vigorous trees than on weaker ones; from two thirds of the number down to one third. Lateral shoots which are badly lighted by reason of their position or direction should be completely removed.

In its second season, the lateral left unpruned after one year's growth has usually made numerous fruit buds as well as a new terminal shoot. The average normal treatment is merely to cut off the latter to concentrate energy in the part bearing fruit buds. With very vigorous trees,

all pruning of these two-year laterals may be omitted. On weak trees, or where fruit size is especially important, they may be cut back into two-year wood to reduce the number of fruit buds by up to a half or even down to about four per lateral.

Three-year laterals should have borne fruit and may be removed completely, or they may be cut back to a stub about 3 in. long if they are in a position from which the growth of a new lateral would be useful. Sometimes, if sufficiently well placed, they may be left to form new branches, or be cut back to laterals already growing from them.

SPUR SYSTEMS

The spur systems on the branches should be prevented from becoming too crowded, complicated and weak by cutting them to leave fewer fruit buds on each.

Advantages of the Renewal System

Renewal pruning aims at producing growths from points where they will be of greatest value for branch formation or for fruiting. The system is one of lighter pruning than the earlier practice; it allows the tree to increase quickly in size and bearing capacity as well as to crop at an earlier age. When ageing and weakening branches need replacement by younger ones, these are already being fostered for the purpose.

Dessert apples on young trees, especially the fruits borne on unpruned laterals drooping outward under their weight, are of better quality than fruits of otherwise comparable trees pruned severely. Flowers on the unpruned laterals open one or two days later than those on other parts of the tree, and this lengthens the period in which the setting of fruit can take place. This may, however, be a slight disadvantage from the point of view of the spray programme.

It is claimed that Apple mildew is encouraged by the absence of shoot tipping. However, where this disease is feared there is no reason why the terminal two inches should not be removed from shoots which would otherwise remain uncut.

In a pruning experiment at East Malling Research Station, renewal-pruned trees of Cox's Orange Pippin seven years from planting had yielded more than twice as heavily as trees pruned on the older, established-spur methods. Trees still more lightly pruned, with no leader tipping after two years and no lateral shortening but merely a thinning out of shoots, cropped even more heavily in the same experiment.

In a West Sussex plantation, 381 renewal-pruned Cox trees on M.II bore 181, 391 and 428 bushels of fruit in their fourth, fifth and sixth seasons after planting.

Light pruning methods have proved their worth when intelligently applied and when reasonable shoot growth is maintained.

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